UNCLASSIFIED

(2)

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

SHIP DESIGN AND ENGINEERING DIRECTORATE
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C. 20362

UNCLASSIFIED

UNCLASSIFIED

NAVSEA Technical Note
No. 051-55W-TN-0082
November 1989

PREDICTIONS OF TRANSOM STERN HULL RESISTANCE BY TWO POTENTIAL FLOW PANEL METHODS

DISTRIBUTION STATEMENT
Approved for Public Release:
Distribution Unlimited

Prepared by
Chu Chen
Hull Form and Hydrodynamic Performance Division (Code 55W3)

Ship Design and Engineering Directorate
Naval Sea Systems Command
Washington, D.C. 20362-5101

Approved Edward N Comstock SEA 55W3
Edward N. Comstock

Date 18 December 1989

UNCLASSIFIED

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS: NONE
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: UNLIMITED
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): NAVSEA TN NO. 051-55W-TN-0082	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Naval Sea Systems Command — 6b. OFFICE SYMBOL (If applicable): NAVSEA 55W33	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code): Washington, DC 20362-5101	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Naval Sea Systems Command — 8b. OFFICE SYMBOL (If applicable): NAVSEA 55W3	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code): Washington, DC 20362-5101	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

Predictions of Transom Stern Hull Resistance by Two Potential Flow Panel Methods

12. PERSONAL AUTHOR(S)

Y. Chen

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical Note	FROM Feb TO Aug 88	1989 November	ii + 36

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Wave resistance, total hull resistance, transom stern, FFG 7, stern variations, XYZFS, SWIFT

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Two computer programs, XYZFS and SWIFT, for the prediction of ship wave resistance by panel method based on potential flow theory have been under development at DTRC in recent years. In addition to the wave resistance, the total hull resistance is obtained in these two programs with semi-empirical formulations for other resistance components (i.e., form drag and frictional resistance). The present investigation evaluates these two computer programs for their ability to predict total resistance of transom stern hulls. The results of the predictions are compared with U.S. Naval Academy model test data for five stern variants for the FFG 7 class design.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) — 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Two computer programs, XYZFS and SWIFT, for the prediction of ship wave resistance by panel method based on potential flow theory have been under development at DTRC in recent years. In addition to the wave resistance, the total hull resistance is obtained in these two programs with semi-empirical formulations for other resistance components (i.e., form drag and frictional resistance). The present investigation evaluates these two computer programs for their ability to predict total resistance of transom stern hulls. The results of the predictions are compared with U. S. Naval Academy model test data for five stern variants for the FFG 7 class design.

INTRODUCTION

Recent advances in numerical hydrodynamics have shown promising results which could be very useful for early stage hull form design. Two theoretical computation methods (as represented in computer programs XYZFS and SWIFT) for wave resistance, based on potential flow theory, have been under development at DTRC in recent years. In addition to the wave resistance, the total hull resistance is obtained in these computations with semi-empirical formulations for other resistance components. The present investigation is an attempt to evaluate these two computer programs for their ability to predict total resistance of transom stern hulls, based on the comparison with model experimental data. This evaluation is performed from the engineering application point of view and no attempt is made to identify differences which may exist either in the basic assumptions or in the detailed methods of computation for these two computer programs.

The experimental data used for comparison with the predictions were obtained from the U.S. Naval Academy (USNA) (Ref. 1). Five model hulls with a common forebody were tested with a variation of transom stern draft and beam. These hull forms are variations of the modern frigate FFG 7. A portion of the numerical results (from XYZFS computation) have been provided to USNA and reported in Ref. 1. This report presents detailed comparisons of total resistance predictions from the two computer programs, XYZFS (Ref. 2) and SWIFT, with the model experimental data.

The predictions presented in this report were obtained in the time period from February 1988 to August 1988. Any improvements or modifications to the two programs, XYZFS and SWIFT, which may have been made since then are not reflected in the present results. A new version of the SWIFT program as described in the forthcoming report (Ref. 3) should be evaluated when available.

HULL GEOMETRY

The geometrical variation of the five model hulls (L_{WL}=11.33 ft) in this investigation is reported in Ref. 1. These models having a common forebody and different aftbodies are:

(1) baseline model -- designated as Model A in this study.
(2) deep draft model -- designated as Model B. The draft of this model at transom is 33.8% greater than that of the baseline model.
(3) shallow draft model -- designated as Model C. The draft of this model at transom is 16.0% smaller than that of the baseline model.
(4) narrow beam model -- designated as Model D. The beam of this model at the transom on the design waterline is 16.7% smaller than that of the baseline model.
(5) wide beam model -- designated as Model E. The beam of this model at the transom on the design waterline is 16.7% greater than that of the baseline model.

The transom area and the displacement are held constant for all the five models. The forebody (from station 0 to 10.7 of 20 stations) for these hulls was that of a modified version of FFG 7 class frigate. Each of the five different aftbodies was attached to the same forebody in the experiment and was modeled in the numerical computation.

PANELING

Numerical values representing hull geometry of the five models were obtained through the digitization of the line drawings (1/36 ship scale; the ship waterline length being 408 ft). Paneling data of the hull geometry required to input to XYZFS and SWIFT programs were obtained from the digitized data using the PANHULL program which has been developed by Steven Fisher of DTRC. A total of 280 panels was used to represent the underwater portion of the hull geometry for each of the five hulls. Figs. 1 through 10 show the geometry variation in panel form. The baseline (Model A) body plan is compared with those of the 4 modified models in Figs. 1 to 4. Several profile plans and half-breath plans are illustrated in Figs. 5 to 10 for Models A, B, and C.

NUMERICAL COMPUTATION

The identical set of paneling data for each of the five models were input to run the two potential flow programs, XYZFS and SWIFT, under both model fixed condition and sinkage and trim condition at 11 speeds between Froude numbers Fr=.21 to .63 as listed in Table 1. ($Fr=\sqrt{V/gL}$, V being the speed, g the gravitational constant, and L the waterline length). Note that the higher speeds in the list are outside the ship operation range which is 10 to 30 knots (Fr=.15 to .44). However for completeness, the predictions are made and compared with the model experimental data in the entire speed range of the model test. The computed results for the total resistance coefficient, under both model "fixed" condition and sinkage and trim condition, are illustrated for the baseline (Model A) in Fig. 11 from the XYZFS program and in Fig. 12 from the SWIFT program. Experimental results obtained under sinkage and trim condition are also shown in these figures.

The major effort in the numerical computations is to calculate wave resistance by panel methods based on potential flow theory. Other resistance components (i.e., frictional resistance and form drag) are computed using rather simple semi-empirical formula. The predicted total model resistance is obtained as the sum of wave resistance, frictional resistance and form drag. Since the only resistance quantity measured in the experiment is the total resistance, comparison of prediction and experiment is made only in total resistance coefficient (C_T) in this study.

EXPERIMENTAL DATA

The measured total resistance coefficient C_T for all five models is shown in Fig. 13 as a function of Froude number, Fr. This figure displays the variation in total resistance due to the transom geometrical changes. The narrow beam model (Model D) has shown the highest C_T value in the entire range of the test conditions (Fr=.21 to .63). The lowest C_T value is associated with the wide beam model (AWE). The five models, in order of decreasing values of C_T, are as follows:

narrow beam model (D) ---- Worst case with highest resistance
deep draft model (B)
baseline model (A)
shallow draft model (C)
wide beam model (E) ---- Best case with lowest resistance

This general data trend is clearly shown at high speed (Fr=.42 and above). The shallow draft model (C) and the wide beam model (E) have almost identical C_T values for a large range of Froude numbers.

RESULTS OF COMPUTATION

Since the experimental results (in total resistance coefficient) were obtained under sinkage and trim condition, comparisons of predictions and experiments discussed below are made under such a condition unless noted otherwise.

The XYZFS predictions (Fig. 14) show very similar trends as the experimental results (Fig. 13): namely, with C_T in decreasing order of magnitude are Models D, B, A, C, and E. This trend is clearly shown in the high Froude number range (Fr=.42 to .63). The SWIFT predictions (Fig. 15 with flat panel method and Fig. 16 with curve panel method) fail to follow the experimental data trend.

In Figs. 17 to 20 predictions from the three methods (XYZFS with flat panel method, SWIFT with flat panel method and SWIFT with curve panel method) are shown in comparison with experimental data for Models A, B, C, and E. These results indicate that the differences are quite small between the flat-panel and the curve-panel computation methods. In theory, the curve-panel computation method represents a higher order computation method with linear source density distribution within a panel as compared to the flat-panel method with a constant source density within a panel. At one instance, the curve-panel computation produced a worse prediction in C_T than the flat-panel prediction at Fr=.44 for Model D (See Figs. 15 & 16).

A close examination of the results in Figs. 17 to 20 reveals that the SWIFT program gives extremely good predictions in absolute levels of total resistance coefficient in a small range of Froude number (between Fr=.35 to .42, corresponding to ship speed of 24 to 28.5 knots) for Models A, B and E. However, the predictions for Models C and D are not good.

In order to show more clearly the predictive capability for total resistance due to change in stern geometry, % difference in C_T from the baseline model (A) for a modified model is defined as (Ref. 1):

$$\%\ \text{difference in } C_T = 100 \times (C_T(\text{model } x) - C_T(\text{model A})) / C_T(\text{model A})$$

where model x refers to Model B,C,D or E. The % difference in C_T from XYZFS prediction are shown in comparison with the measurements in Figs. 21 through 24. Similar plots for SWIFT are given in Figs. 25 to 28.

MODEL B (Deep draft model)

Experimental data for the deep draft hull (Model B) show less than 1% change in C_T from the baseline hull (Model A) between Fr=.21 and .50 and slightly higher change (1% to 2%) at higher Froude number. Both XYZFS (Fig. 21) and SWIFT(Fig. 25) predict less than 0.5% variation in C_T from Model A in the whole range of Froude number.

MODEL C (Shallow draft model)

The experimental data show Model C has greater resistance (~1%) than the baseline model in low speeds (Fr=.20 to .35) and lower resistance (0 to 1.8%) in the high speeds (Fr=.35 to .63). XYZFS predicts (Fig. 22) quite well the general data trend while SWIFT predictions differ greatly from the experimental data (Fig. 26).

MODEL D (Narrow beam model)

The experimental results show that Model D has greater resistance (1 to 3.6%) than the baseline model in the entire speed range (Fr=.21 to .63). The XYZFS prediction (Fig. 23) shows the same trend. The SWIFT predictions (Fig. 27) are poor with a large discrepancy from the experimental data.

MODEL E (Wide beam model)

The experimental results show Model E has greater resistance (~2%) than the baseline model in low speeds (Fr=.2 to .31) but lower resistance (1-2%) in higher speeds (Fr=.31 to .63). Both XYZFS (Fig. 24) and SWIFT (Fig. 25) predict this data trend quite well.

MODEL "FIXED" CONDITION

As shown in Figs. 11 and 12, in terms of absolute values of C_T, the predictions under model "fixed" condition do not compare well with the available experimental results which were obtained under sinkage and trim condition. However, in order to see whether the "fixed" condition calculations may yield some useful information on hull geometry variation, the predicted % change in C_T under such a condition are also shown in Figs. 21 to 28. The XYZFS predictions show only small change under the "fixed" and sinkage and trim conditions for two models with draft variation (Figs. 21-24). For the beam variation, the XYZFS predictions under model "fixed" condition are substantially different from sinkage and trim case in high speeds. (Fr=.35 to .63).

SWIFT prediction for the deep draft model (B) also show little change in % difference in C_T between "fixed" and sinkage and trim conditions. For the wide beam model (E), SWIFT "fixed"

condition predictions show little difference in the low speed range (Fr=.2 to .4) but with 1% difference at high speed range (Fr=.4 to .63). For the shallow draft model (C) and the narrow beam model (D) the "fixed" condition predictions are more stable than the sinkage and trim predictions which fluctuate widely with Fr.

In general, under model "fixed" condition, XYZFS predicts quite well the changes in C_T due to the change of stern geometry for all the models. The SWIFT computations under the "fixed" condition (Figs 25 - 28), however, only produced excellent prediction for Model E but fail to predict the C_T changes for the other models (Models B, C and D).

CONCLUSIONS

Based on the present investigation, the following conclusions may be made:

(1) The XYZFS program predicts very well the ranking of all the five transom stern hulls in total resistance in the Froude number range of .37 to .63 (ship speed 25 to 43 knots).

(2) The SWIFT program fails to predict the ranking of the five hulls in total resistance. However, it gives excellent predictions in the absolute level of total resistance coefficient for three models (Models A, B and E) in a small range of Froude number of .35 to .42 (ship speed of 24 to 28.5 knots).

(3) In the low speed range, Fr=.32 (ship speed of 22 knots) and below, both XYZFS and SWIFT predictions do not compare well with the experimental data.

(4) The SWIFT program appeared to generate very erratic predictions in total resistance under the sinkage and trim condition for Models C and D. The reasons for such a behavior are not known.

(5) The difference in the resistance predictions between the curve-panel method and the flat-panel method (in the SWIFT program) is found to be small and insignificant.

(6) A new version of the SWIFT program (Ref. 3) should be evaluated with the same set of experimental data used in this study.

(7) Based on the study, it is considered that the XYZFS program is a useful tool for resistance predictions of alternative transom configurations in the early stage hull form design.

ACKNOWLEDGMENTS

The author would like to express his appreciation to the following persons of David Taylor Research Center for their technical guidance and assistance in setting up and executing various computer programs: To Bill Cheng and Janet Dean for the XYZFS program, to C. W. Lin and S. H. Kim for the SWIFT program, and to Henry Liu and Steven Fisher for the PANHULL and plotting programs.

REFERENCES

(1) Kiss, Thomas K.,"The Effects of Transom Geometry on the Resistance of Large Surface Combatants", Report No. 151, Trident Scholar Project, United States Naval Academy, 1988

(2) Cheng, Bill H. and Dean, Janet S., "User's Manual for the XYZ Free Surface Program", Report No. DTNSRDC-86/029, David W. Taylor Naval Research and Development Center, June 1986

(3) Kim, Yoon-Ho; Kim, Sea-Hean and Lucas, Thomas."Advanced Panel Method for Ship Wave Inviscid Flow Theory (SWIFT)", Report No. DTRC-89/029, David Taylor Research Center, November 1989.

TABLE 1

List of Model/Ships Speeds at which Computations were carried out

Fr	Model Test Speed (ft/sec)	Equivalent Ship Speed (knots)
.2095	4	14.22
.2619	5	17.80
.3143	6	21.32
.3666	7	24.88
.4190	8	28.43
.4402	8.5	30.22
.4714	9	32.00
.4976	9.5	33.77
.5238	10	35.77
.5762	11	39.11
.6285	12	42.66

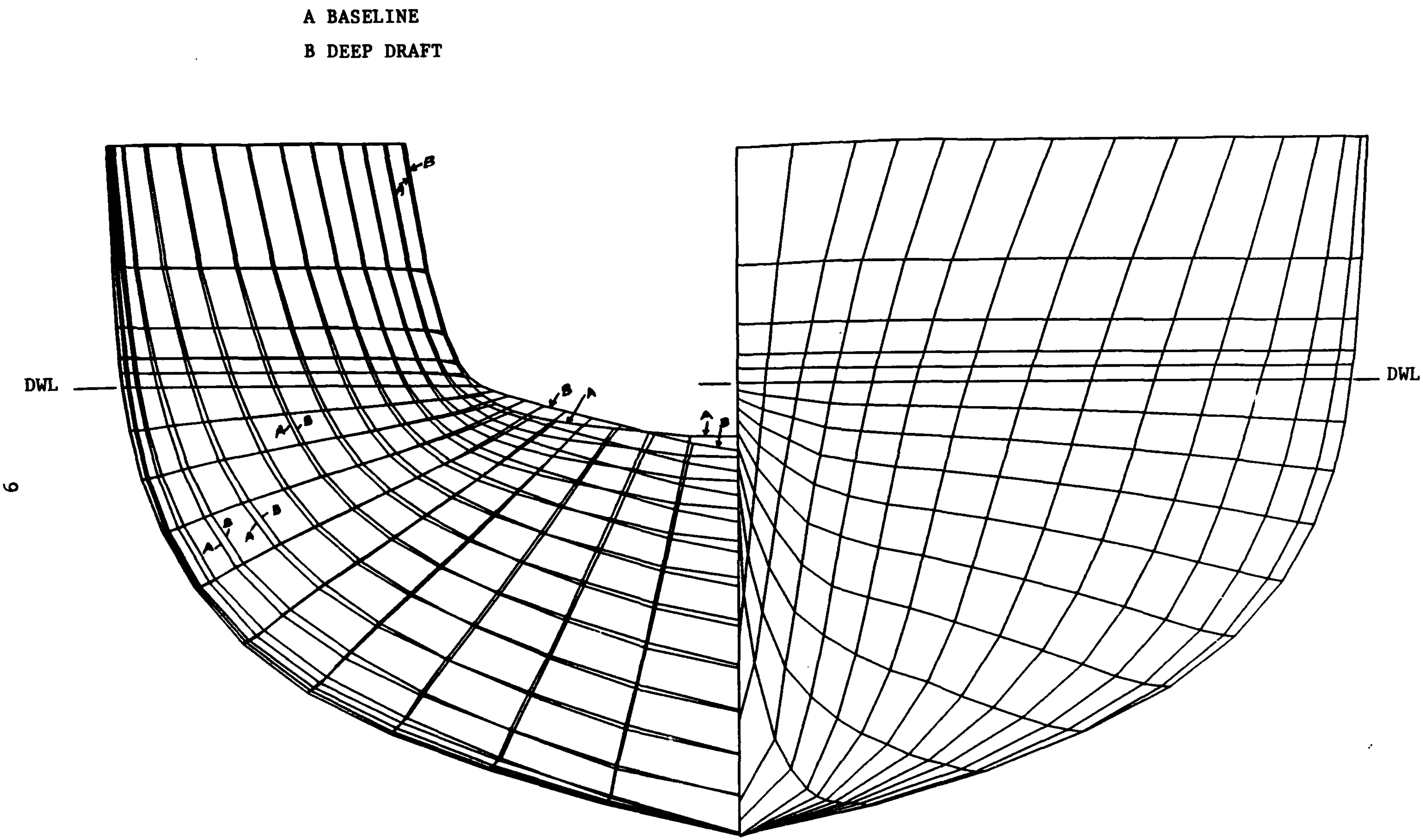


FIG. 1. BODY PLAN COMPARISON

A BASELINE

C SHALLOW DRAFT

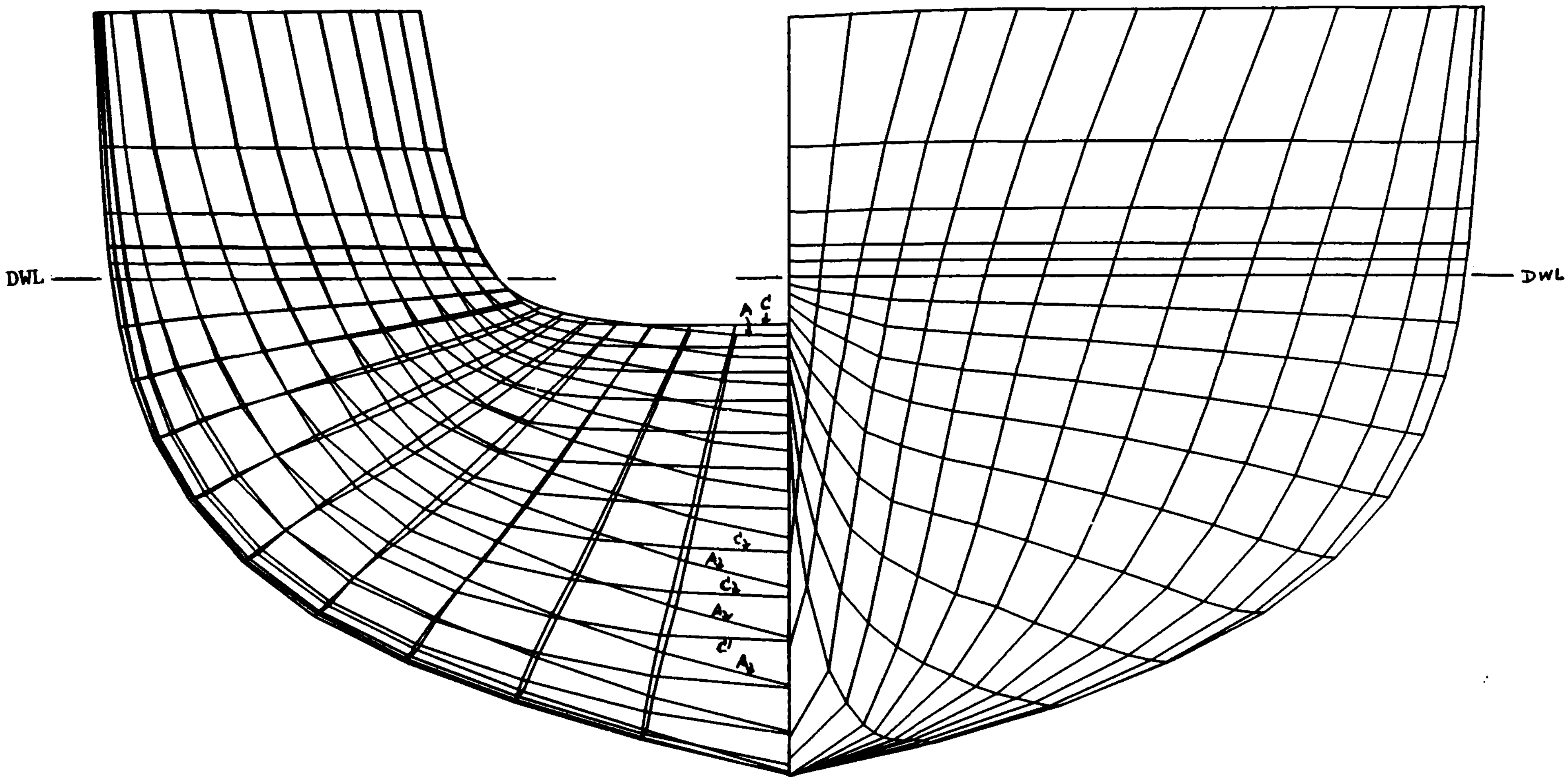


FIG. 2. BODY PLAN COMPARISON

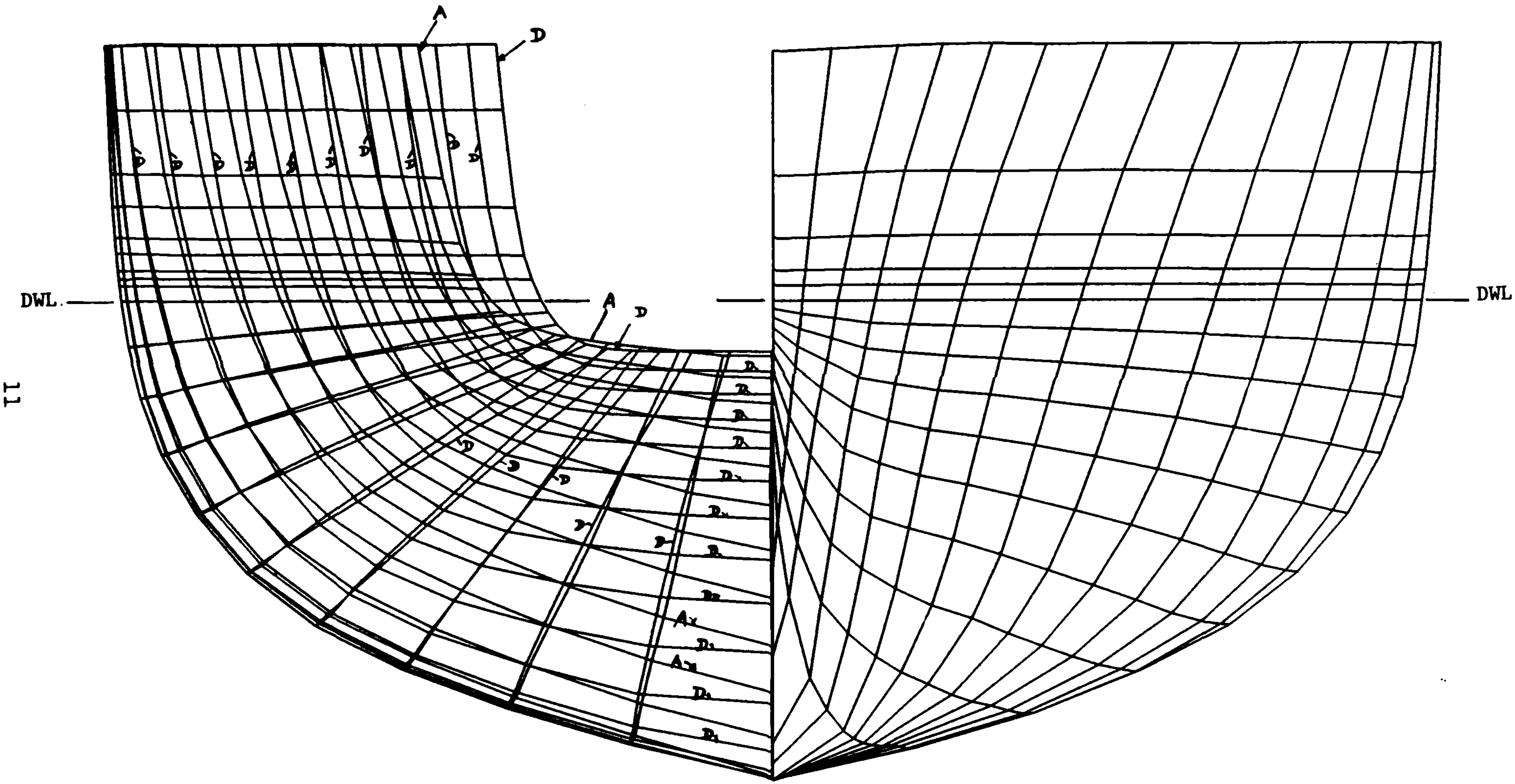


FIG. 3 BODY PLAN COMPARISON

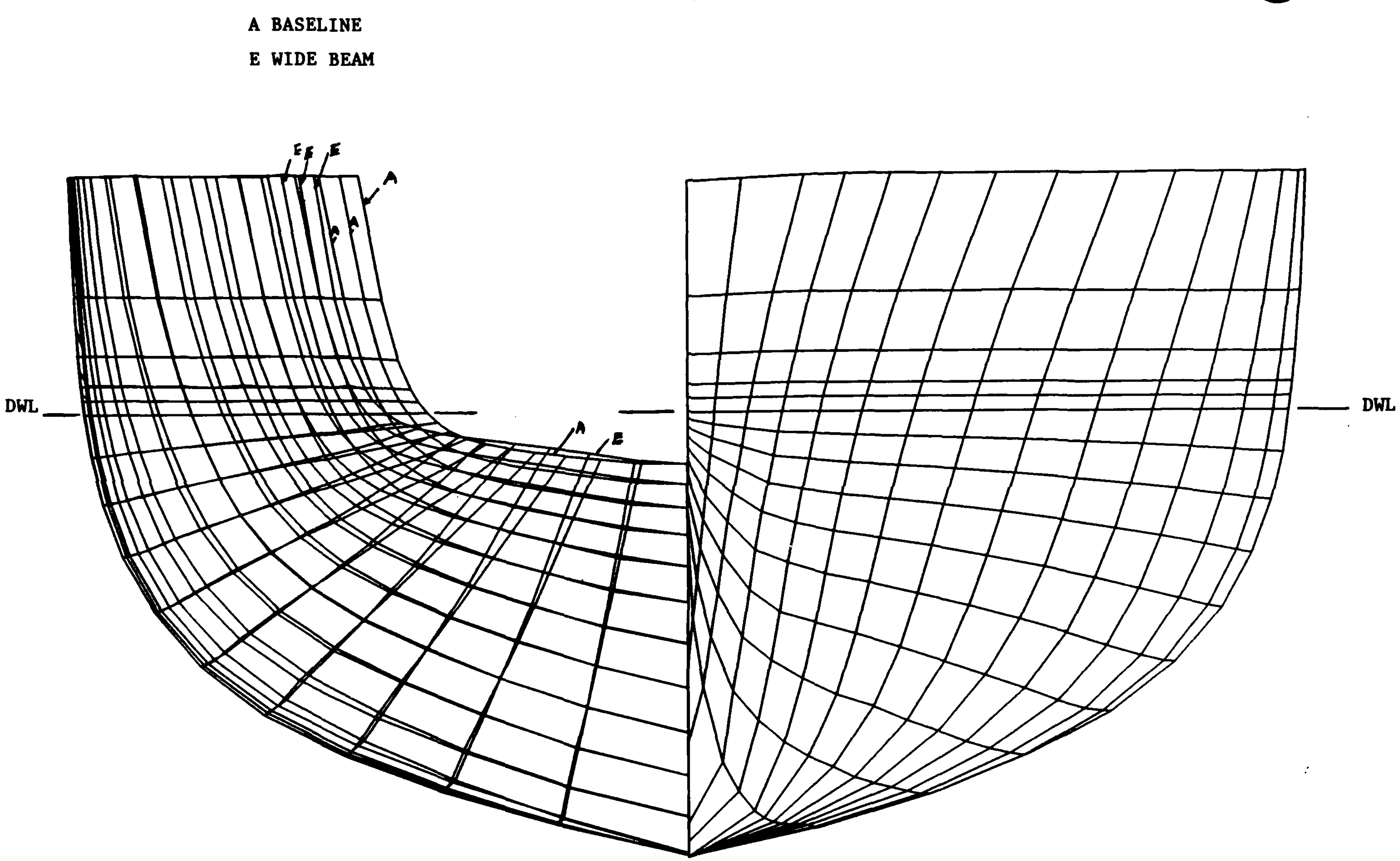
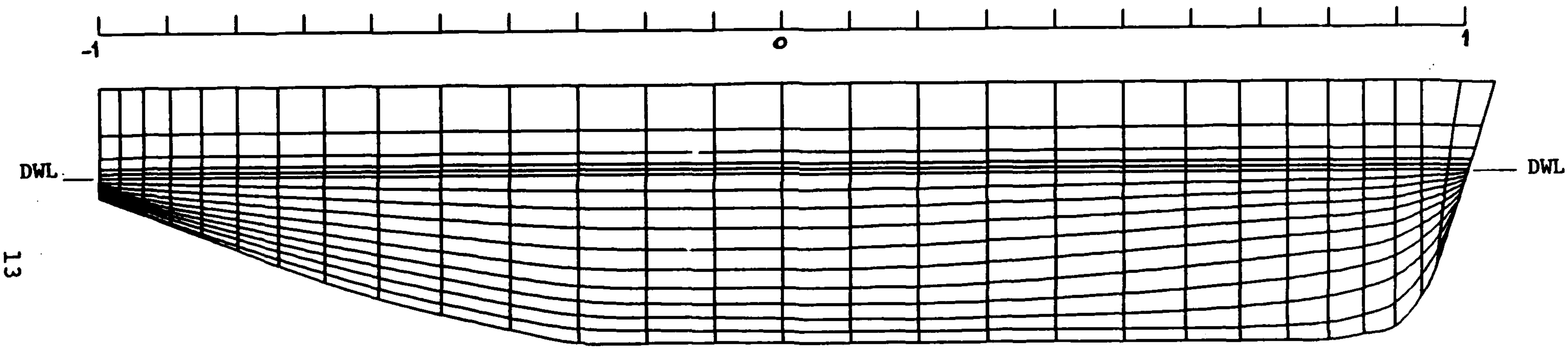


FIG. 4. BODY PLAN COMPARISON

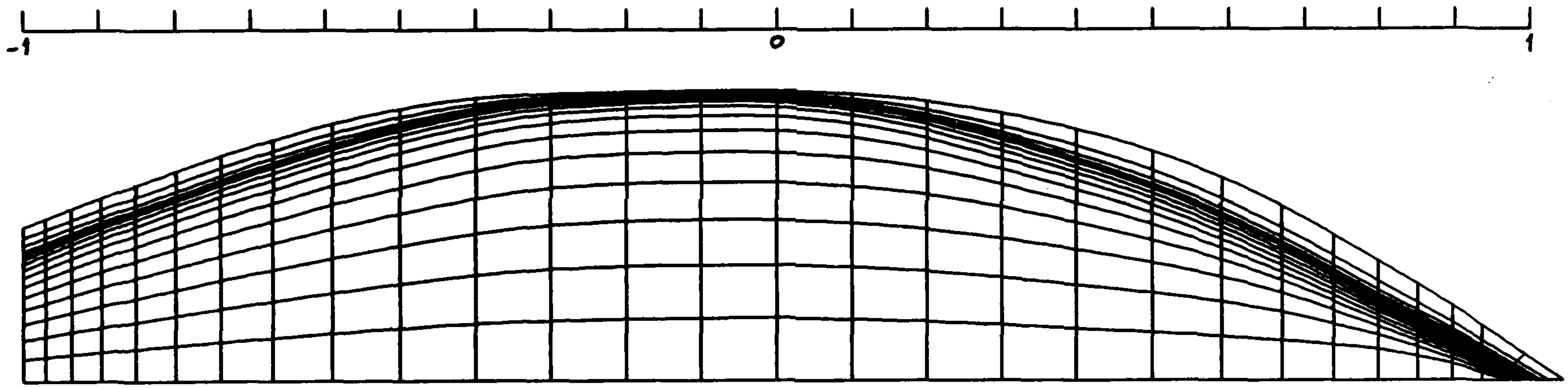
BASELINE MODEL A



HORIZONTAL SCALE: 1
VERTICAL SCALE: 3

FIG. 5. PROFILE

BASELINE MODEL A

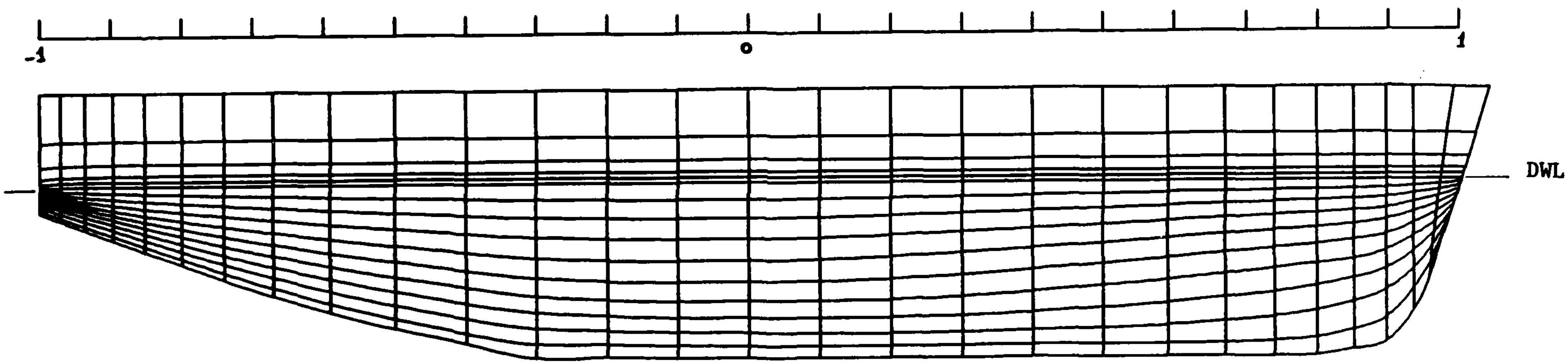


HORIZONTAL SCALE : 1

VERTICAL SCALE: 3

FIG. 6. HALF-BREADTH PLAN

DEEP DRAFT MODEL B

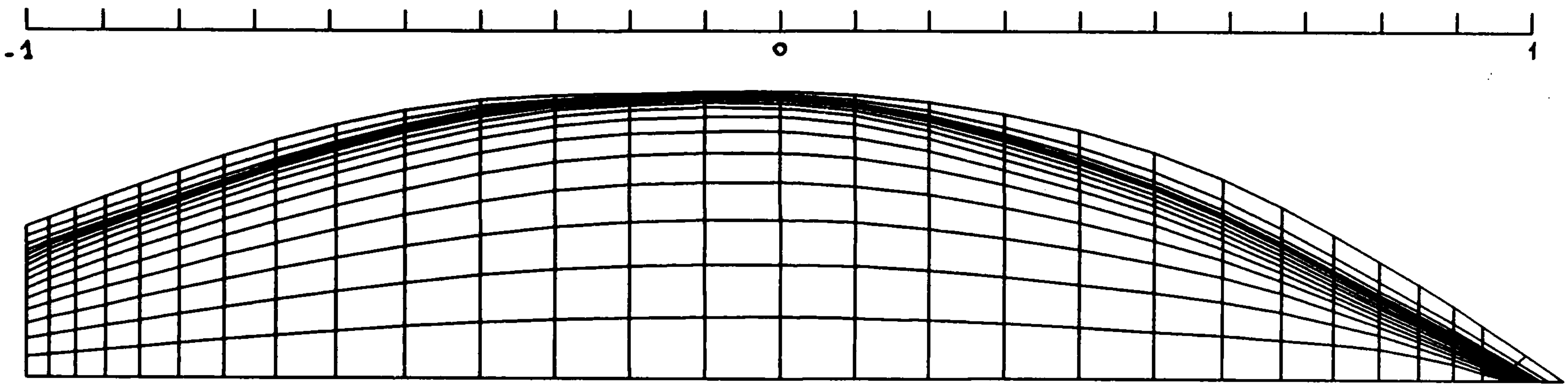


HORIZONTAL SCALE: 1

VERTICAL SCALE: 3

FIG. 7. PROFILE

DEEP DRAFT MODEL B

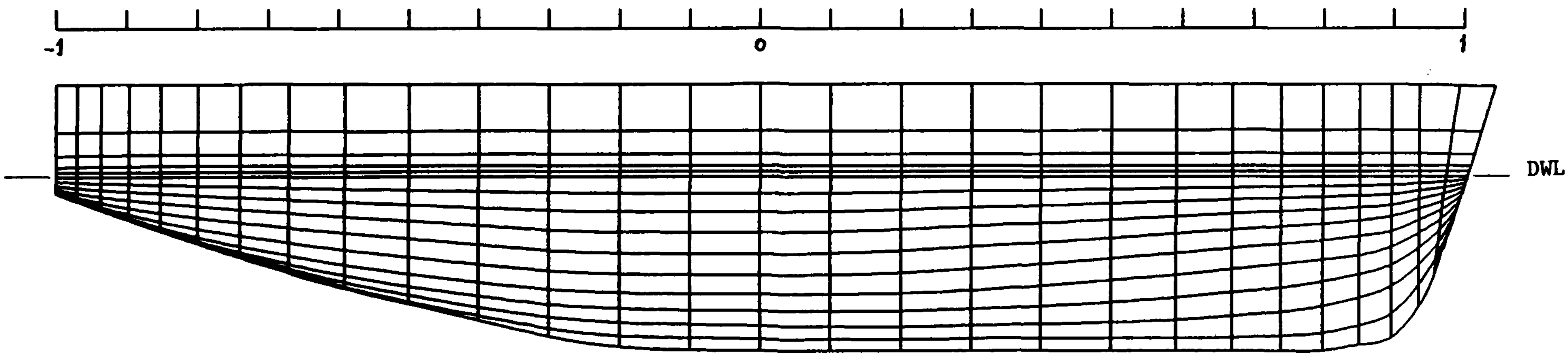


HORIZONTAL SCALE: 1

VERTICAL SCALE: 3

FIG. 8. HALF-BREADTH PLAN

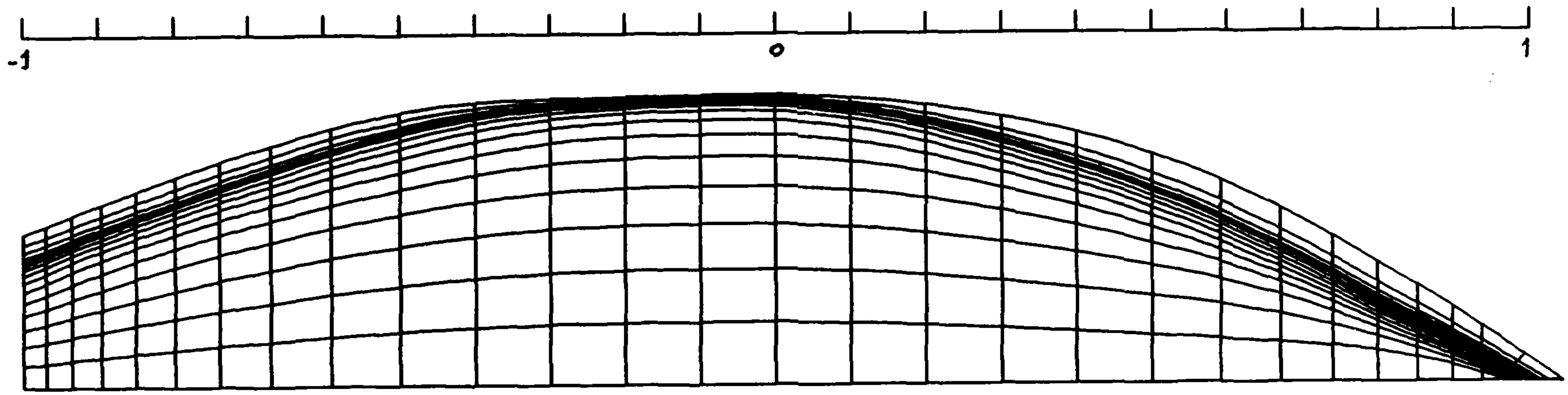
SHALLOW DRAFT MODEL C



HORIZONTAL SCALE: 1
VERTICAL SCALE: 3

FIG. 9. PROFILE

SHALLOW DRAFT MODEL C



HORIZONTAL SCALE: 1
VERTICAL SCALE: 3

FIG. 10. HALF-BREADTH PLAN

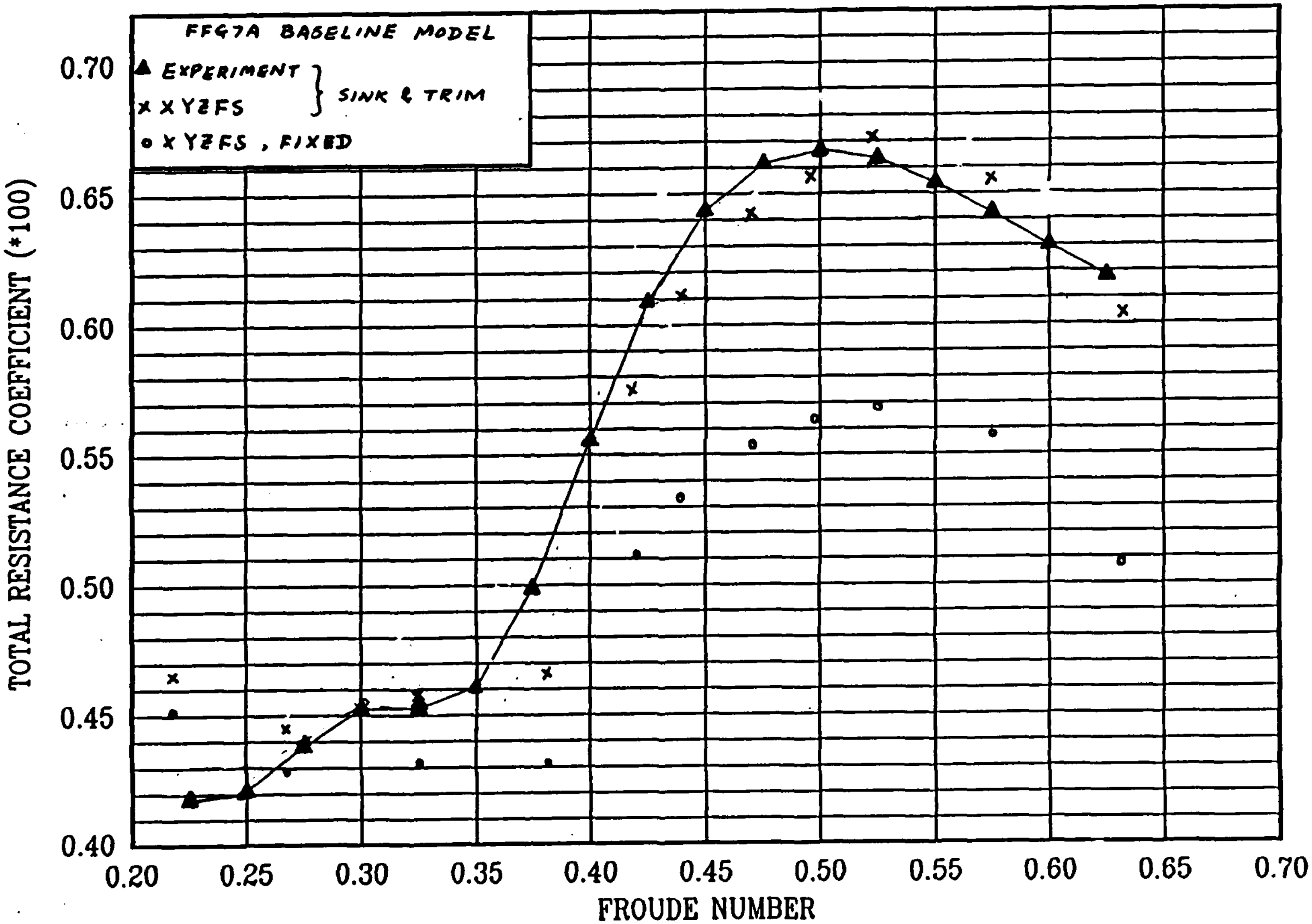


FIG. 11 COMPARISON OF EXPERIMENT & PREDICTIONS

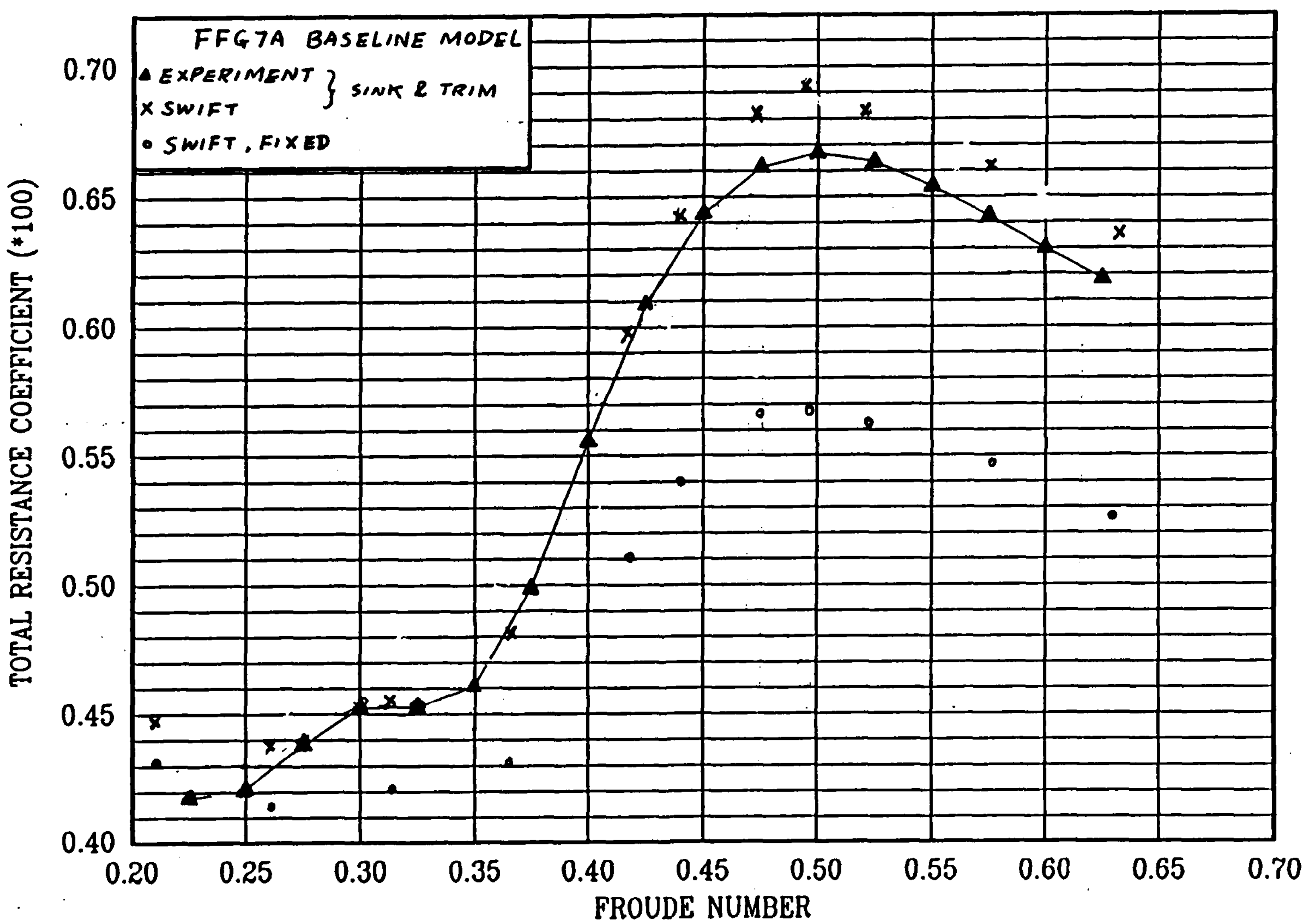


FIG. 12 COMPARISON OF EXPERIMENT & PREDICTIONS

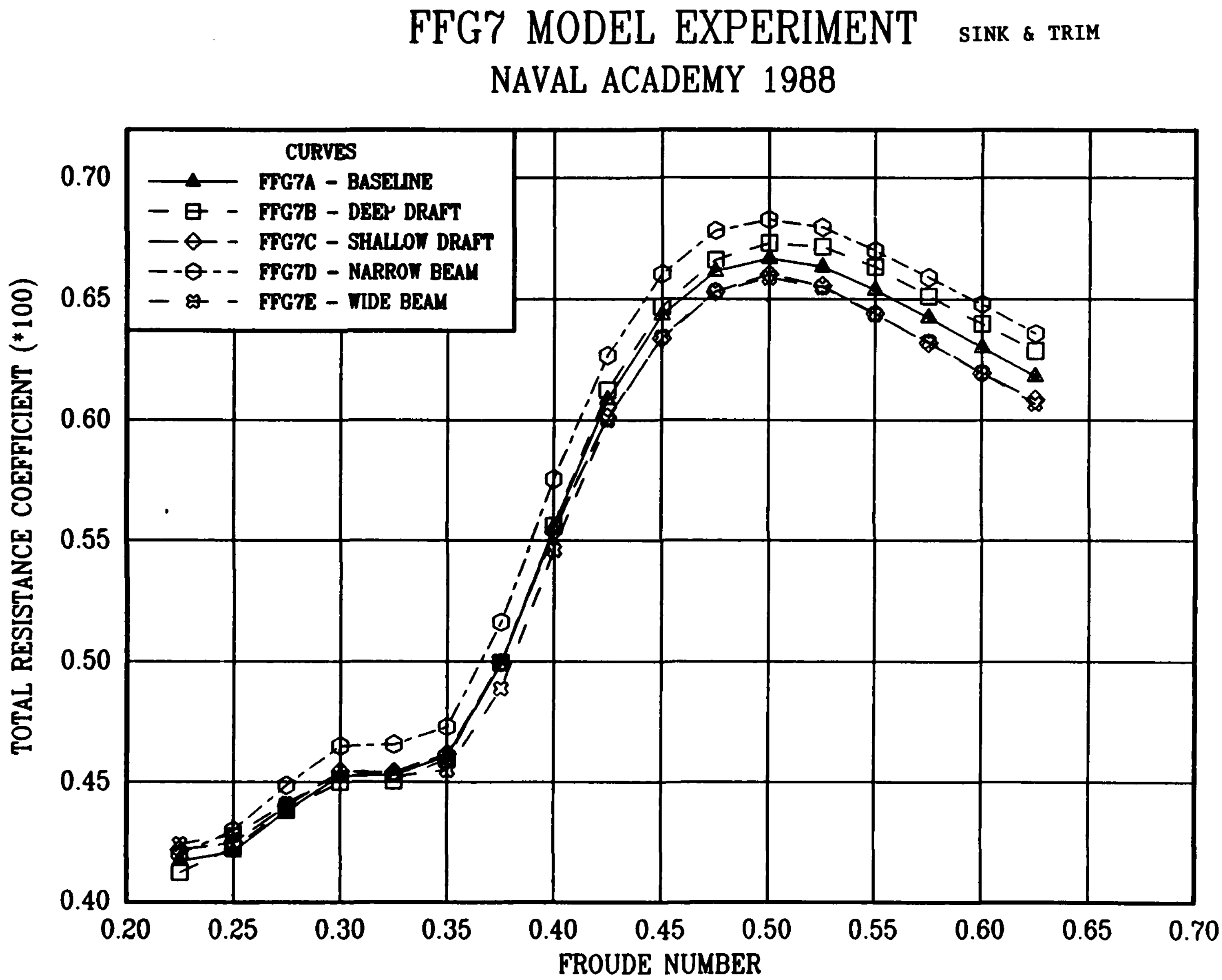


FIG. 13 EXPERIMENTAL RESULTS

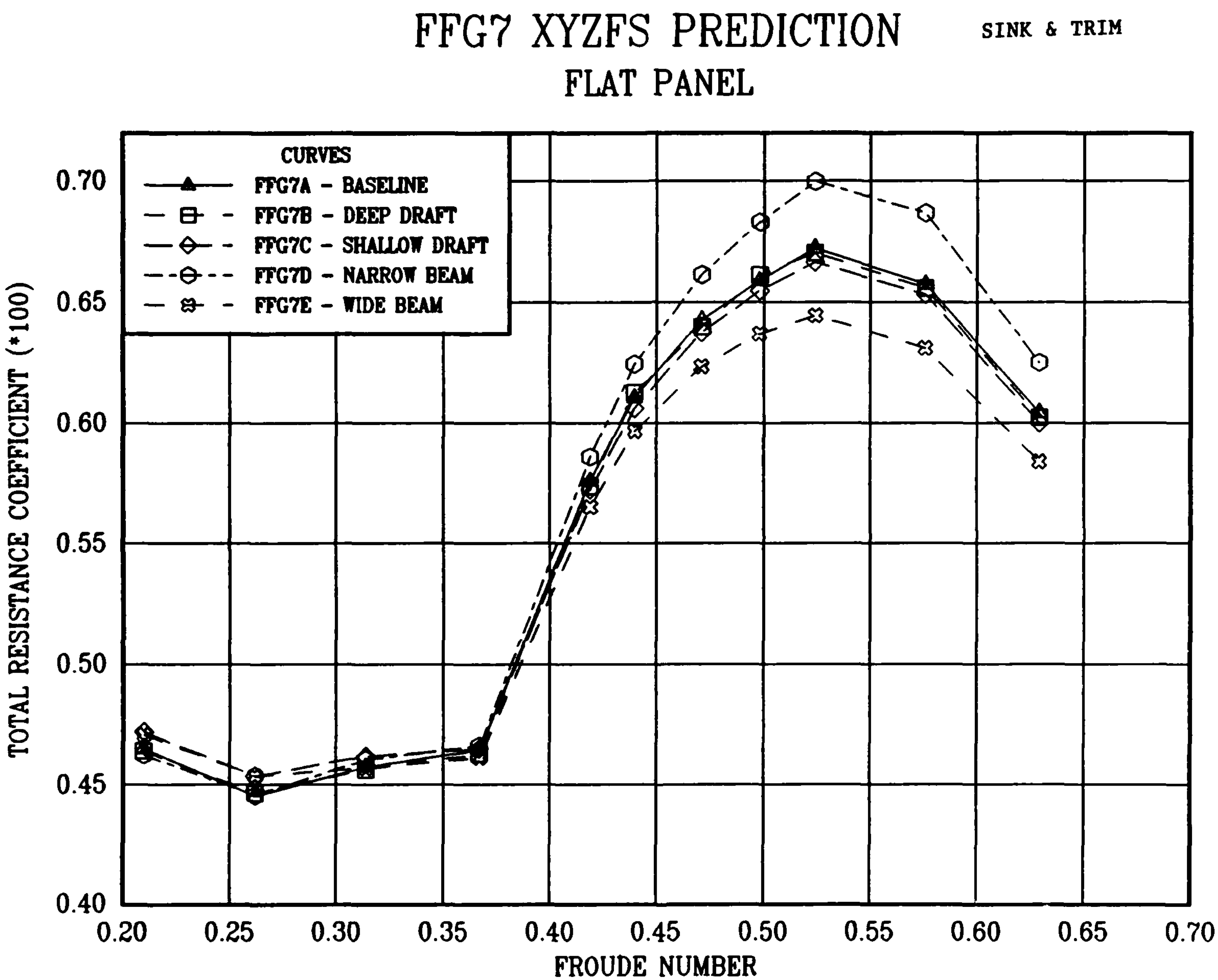


FIG. 14 XYZFS PREDICITION (FLAT PANEL)

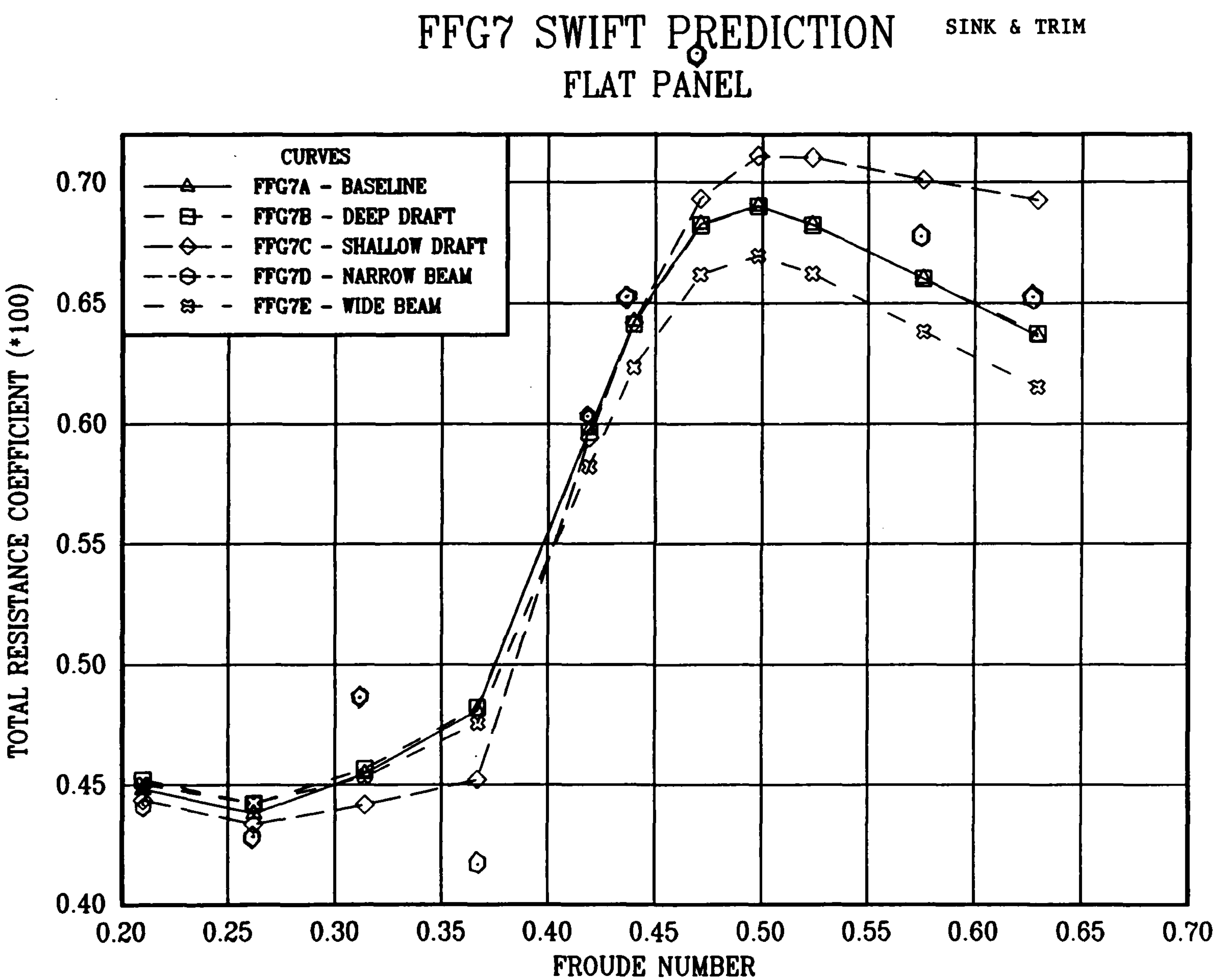


FIG. 15 SWIFT PREDICTION (PLAT PANEL)

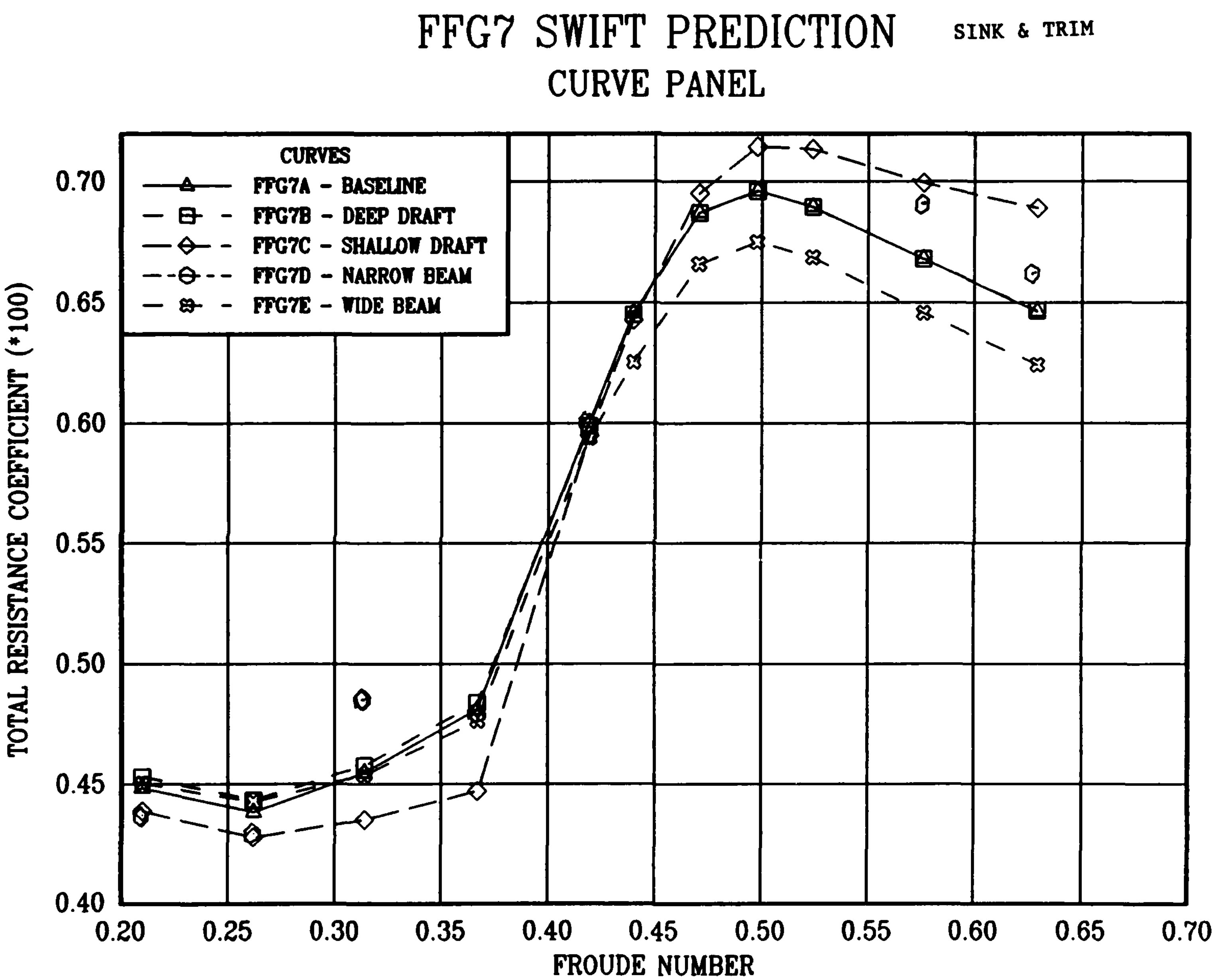


FIG. 16 SWIFT PREDICTION (CURVE PANEL)

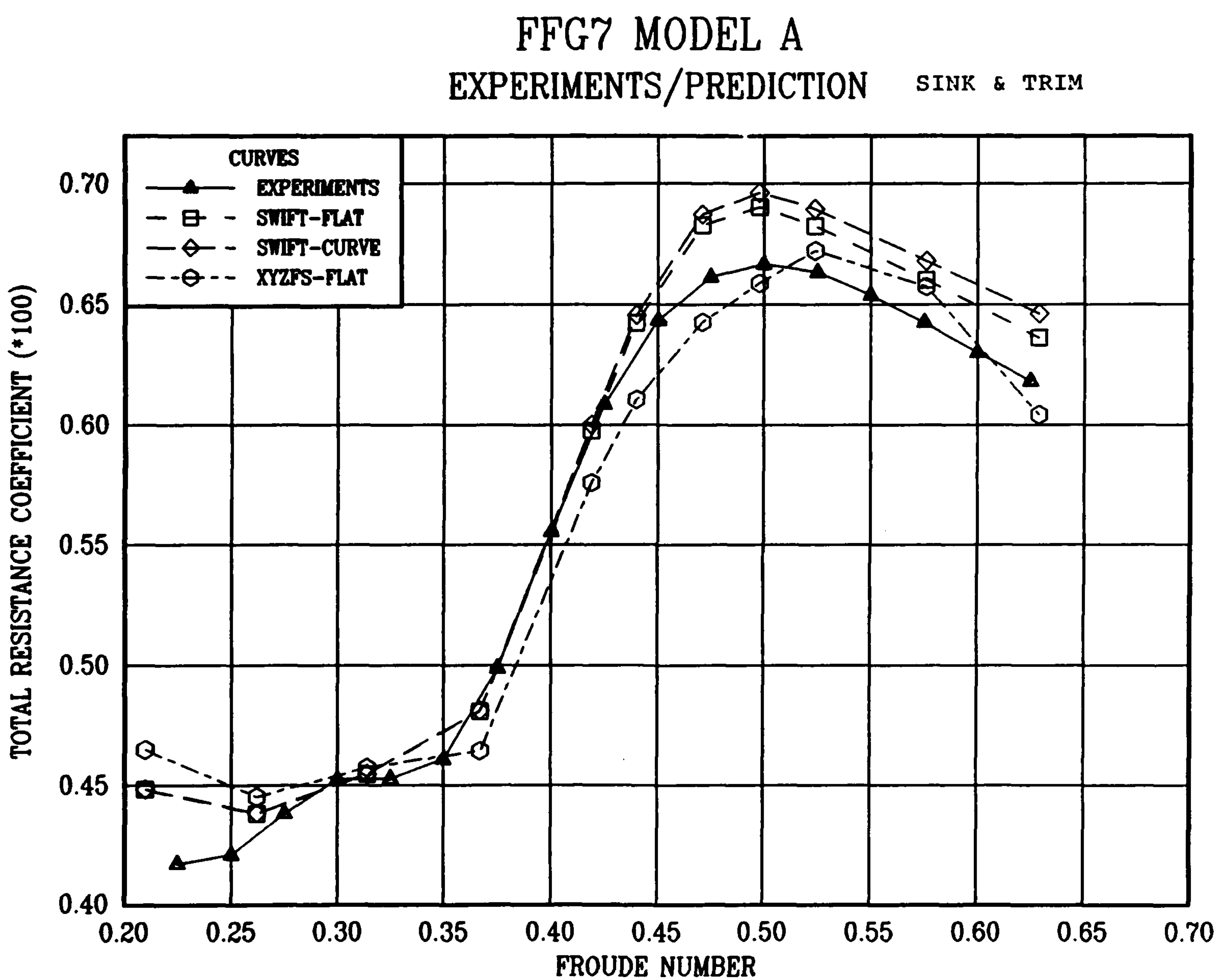


FIG. 17 COMPARISON OF EXPPERIMENT & PREDICTION

BASELINE MODEL A

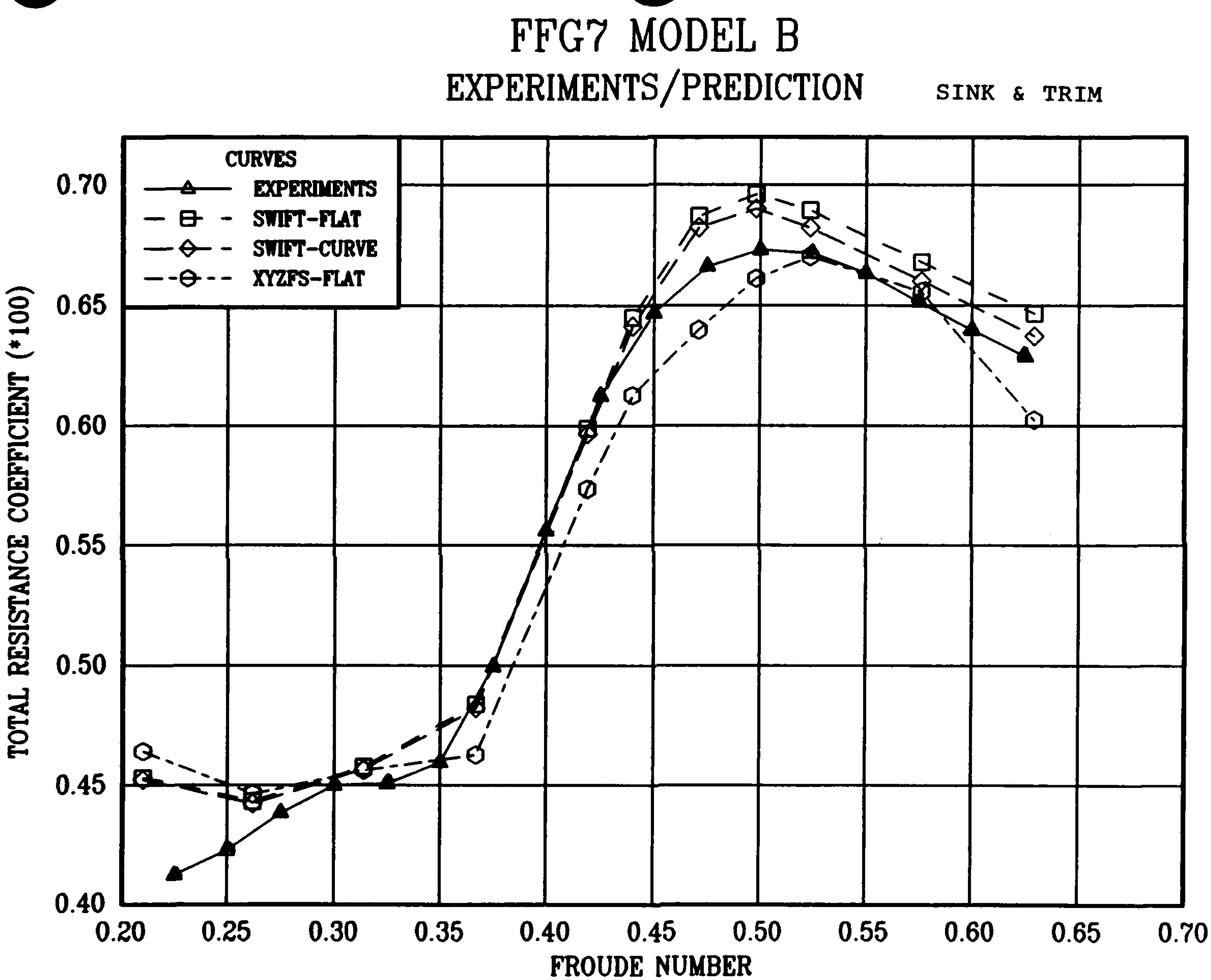


FIG. 18 COMPARISON OF EXPERIMENT & PREDICTION
DEEP DRAFT MODEL B

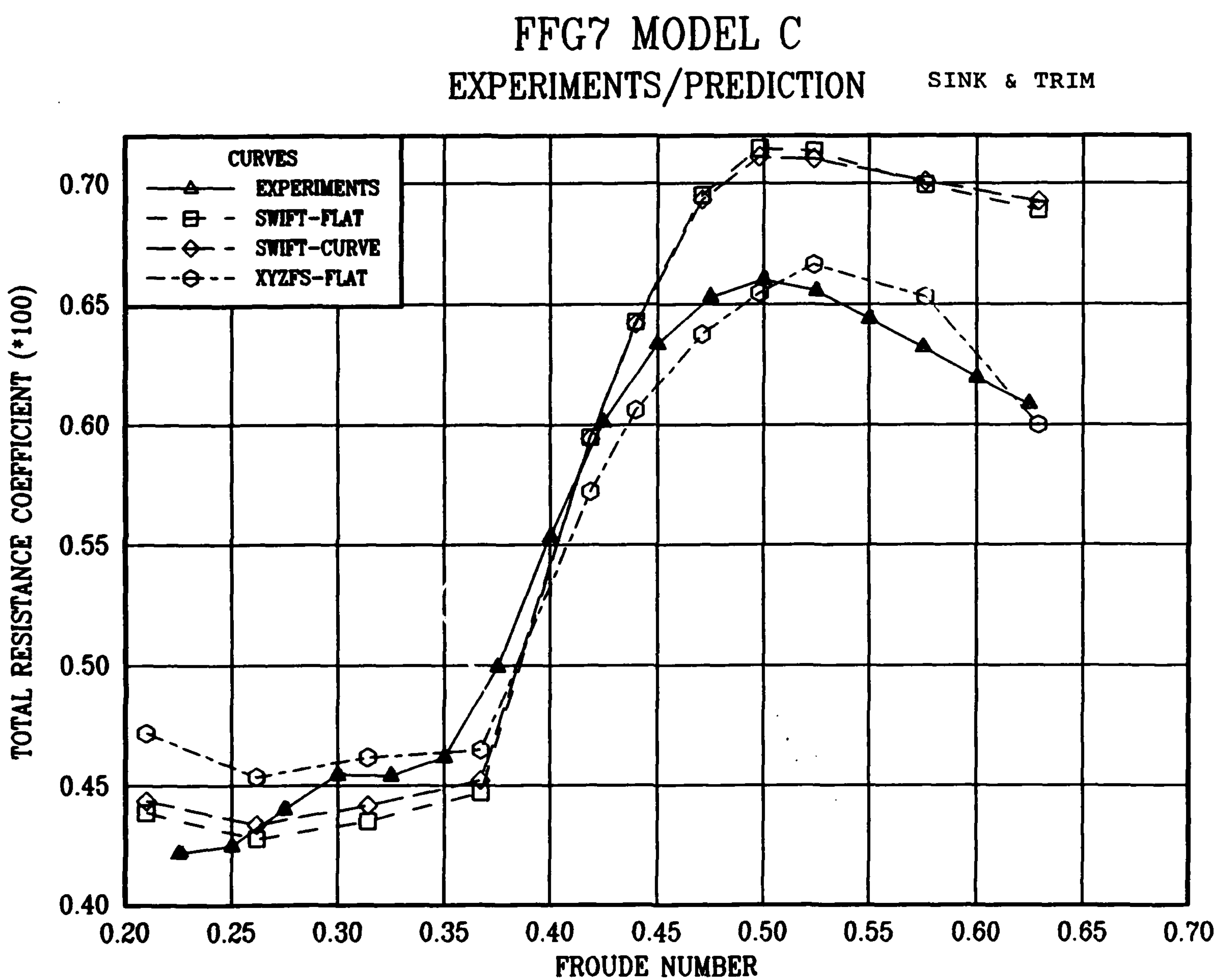


FIG. 19 COMPARISON OF EXPERIMENT & PREDICTION
SHALLOW DRAFT MDOEL C

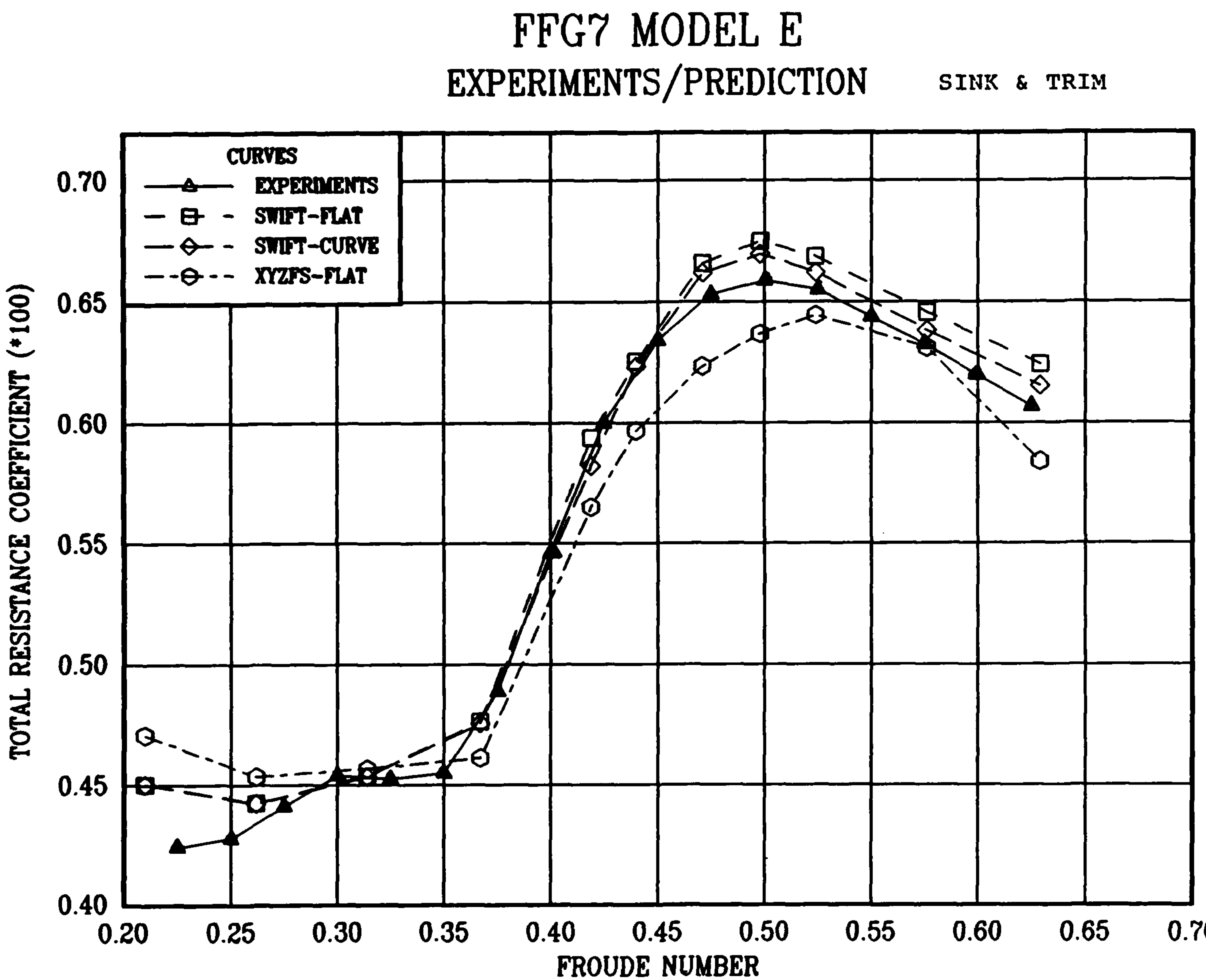


FIG. 20 COMPARISON OF EXPERIMENT & PREDICTION
WIDE BEAM MODEL E

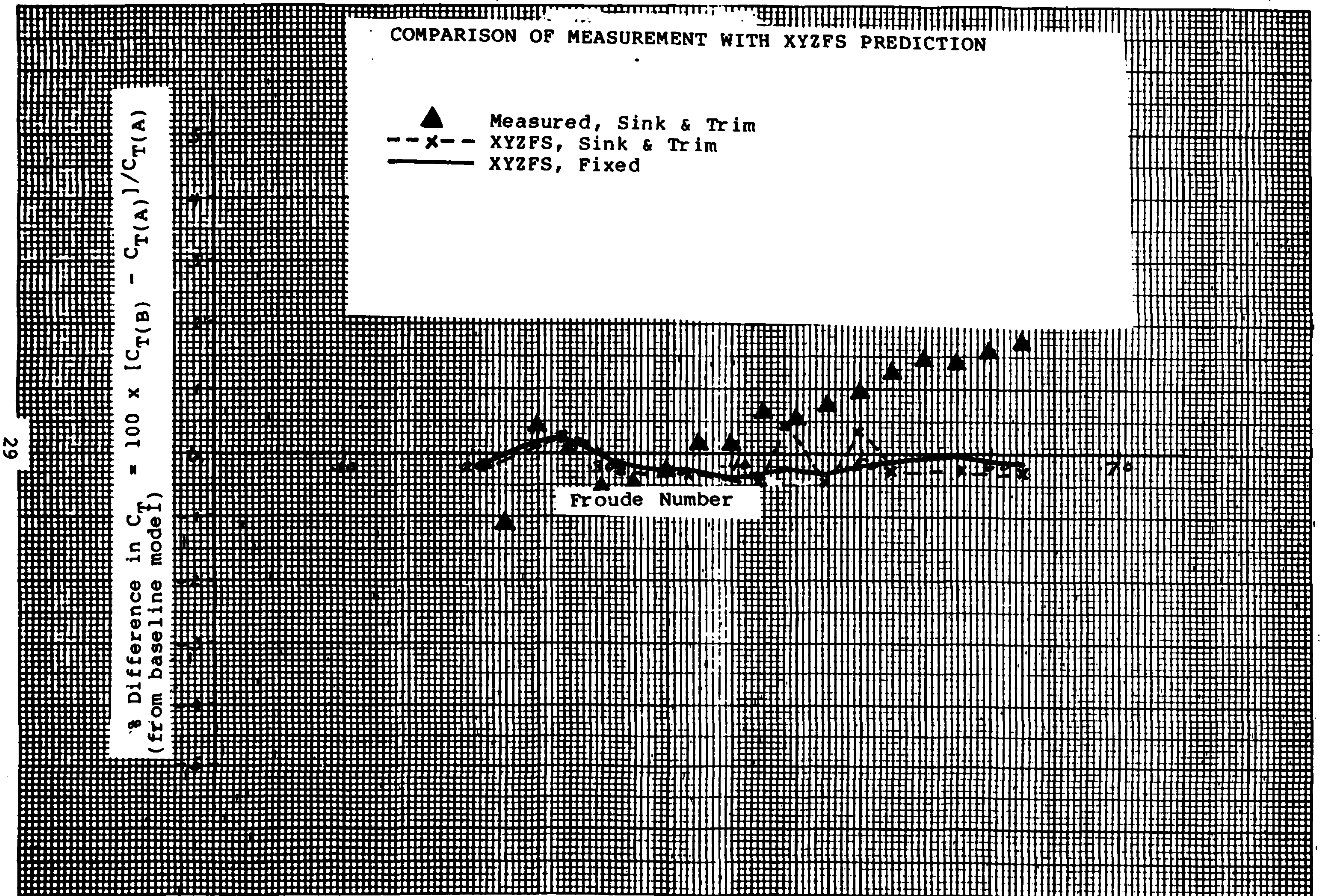


FIG. 21 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL B)

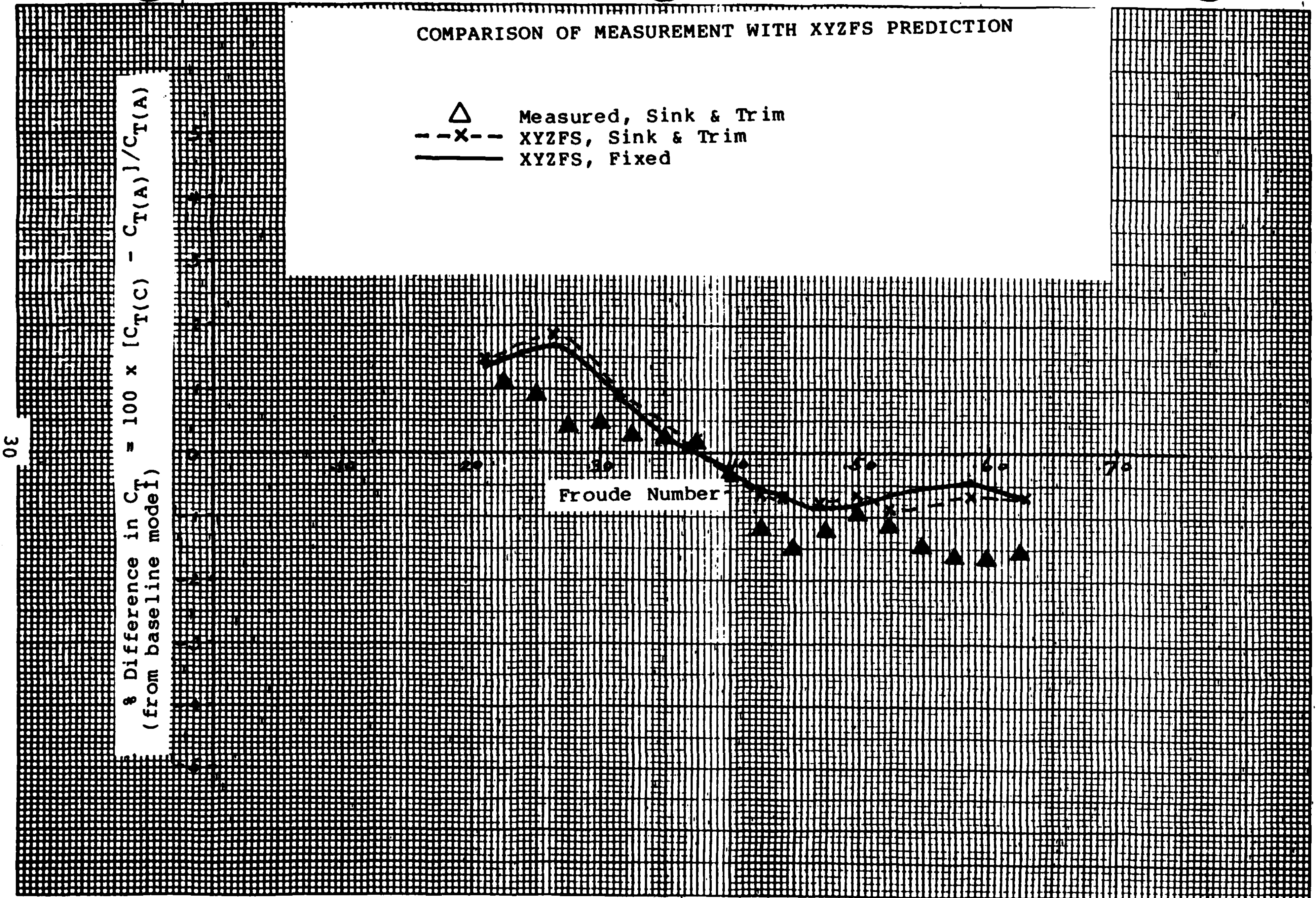


FIG. 22 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL C)

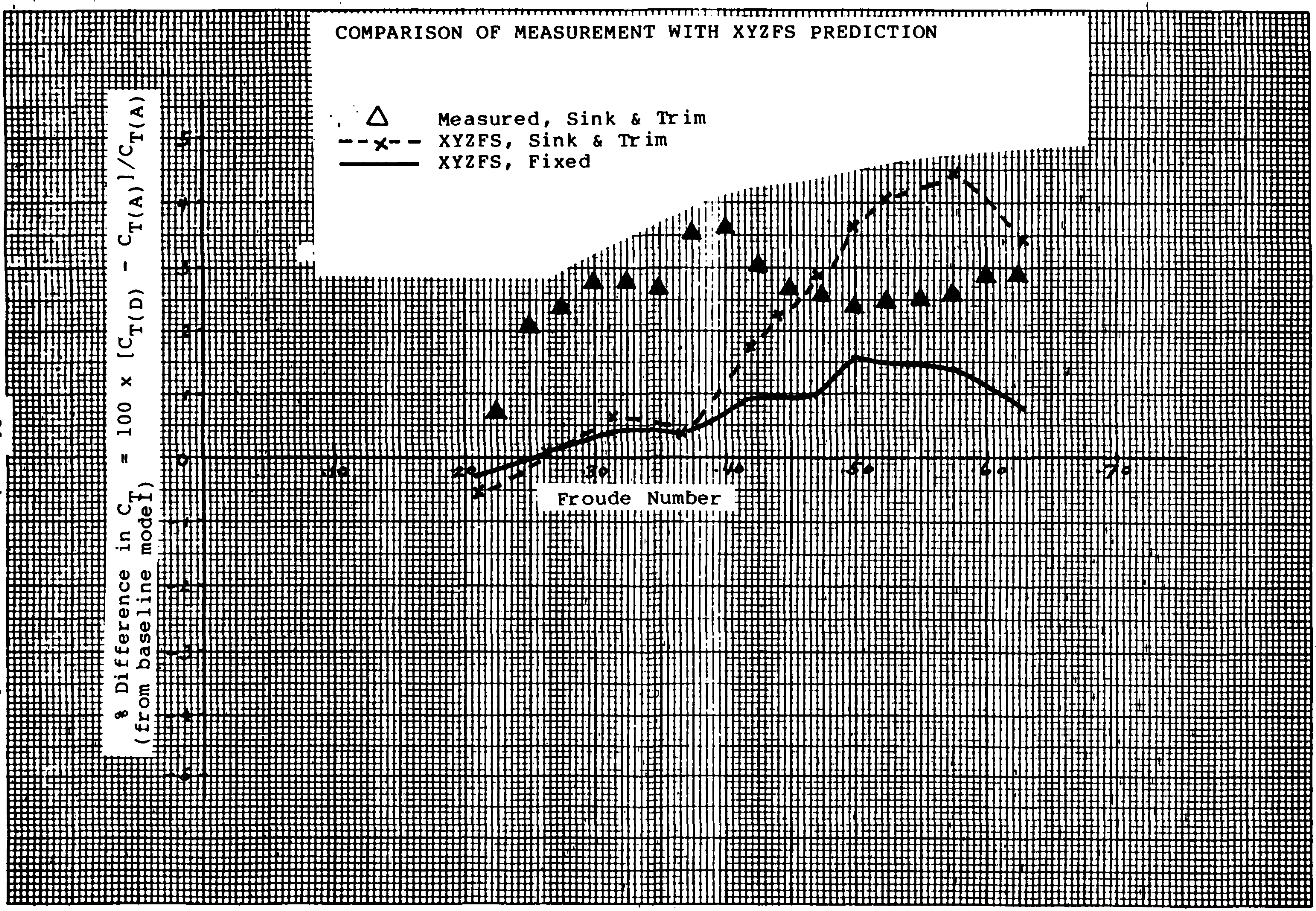


FIG. 23 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL D)

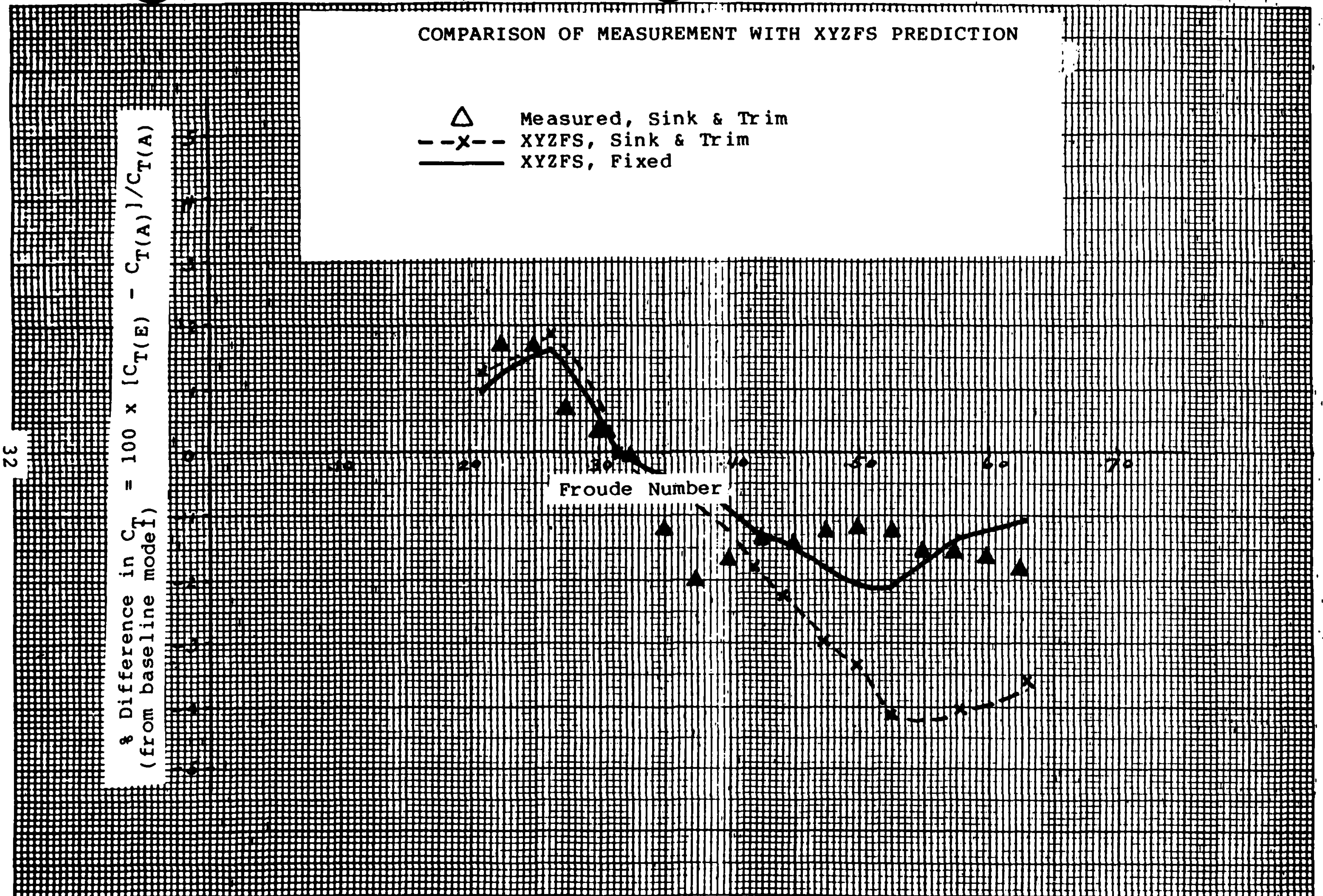


FIG. 24 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL E)

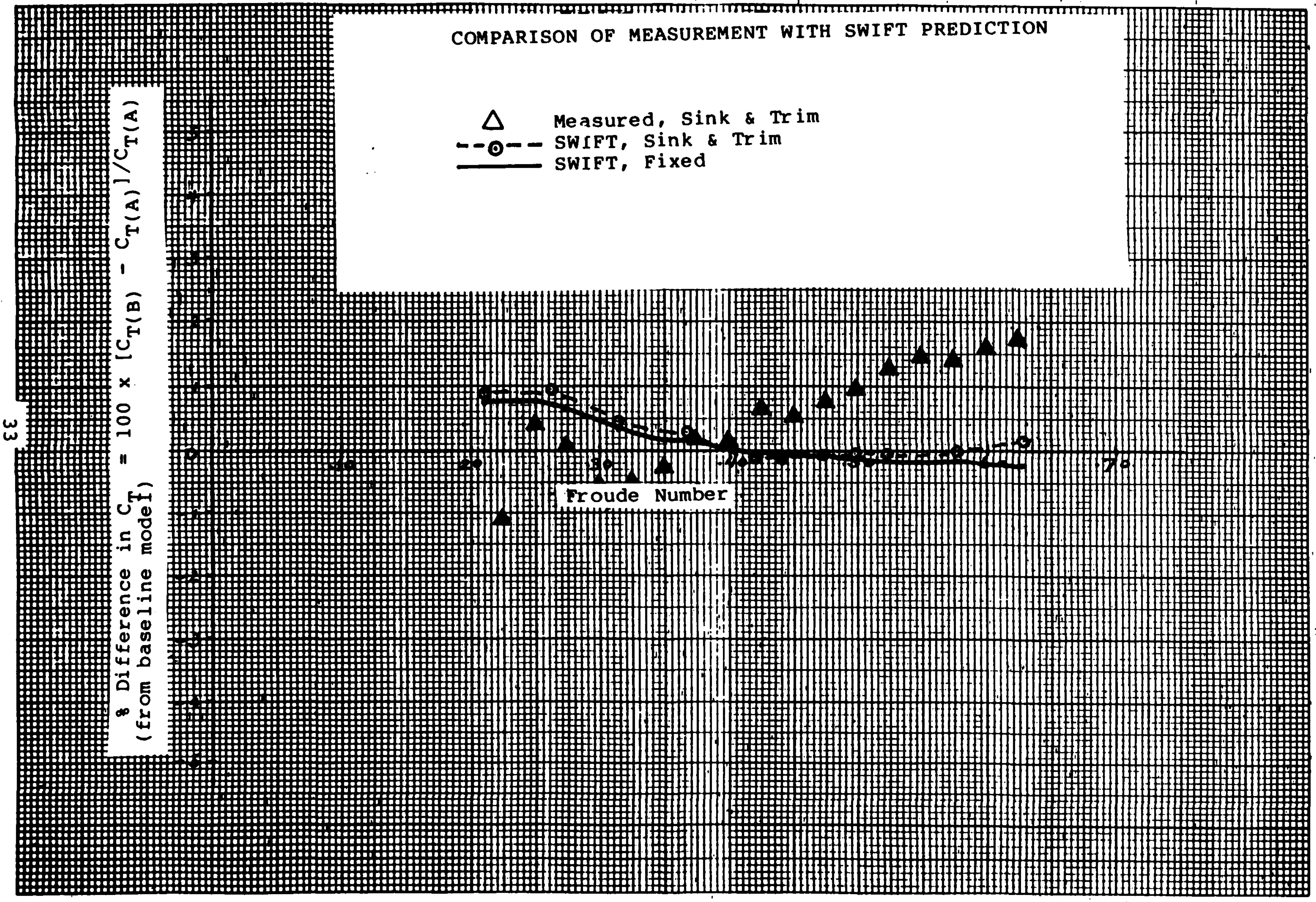


FIG. 25 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL B)

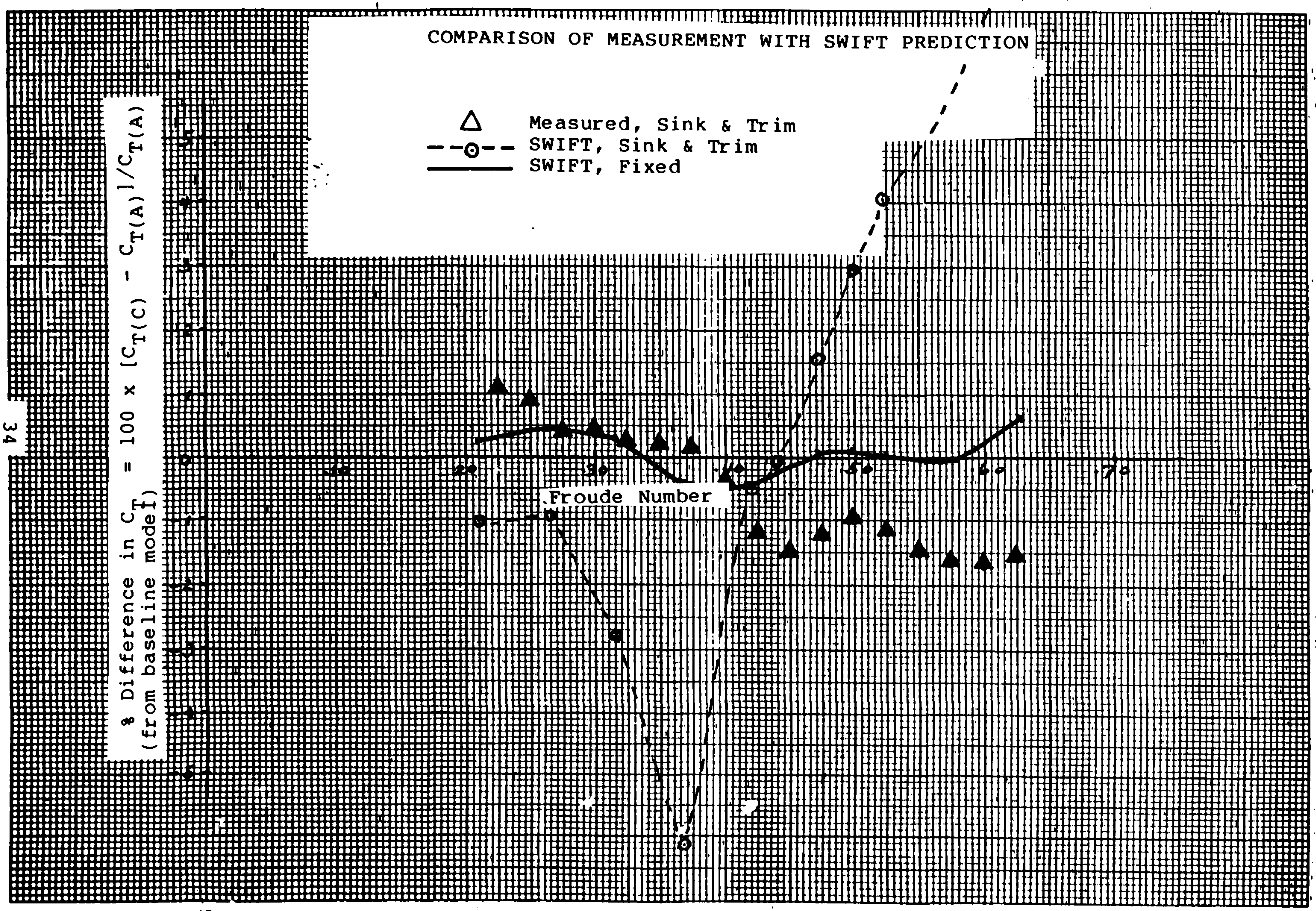


FIG. 26 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL C)

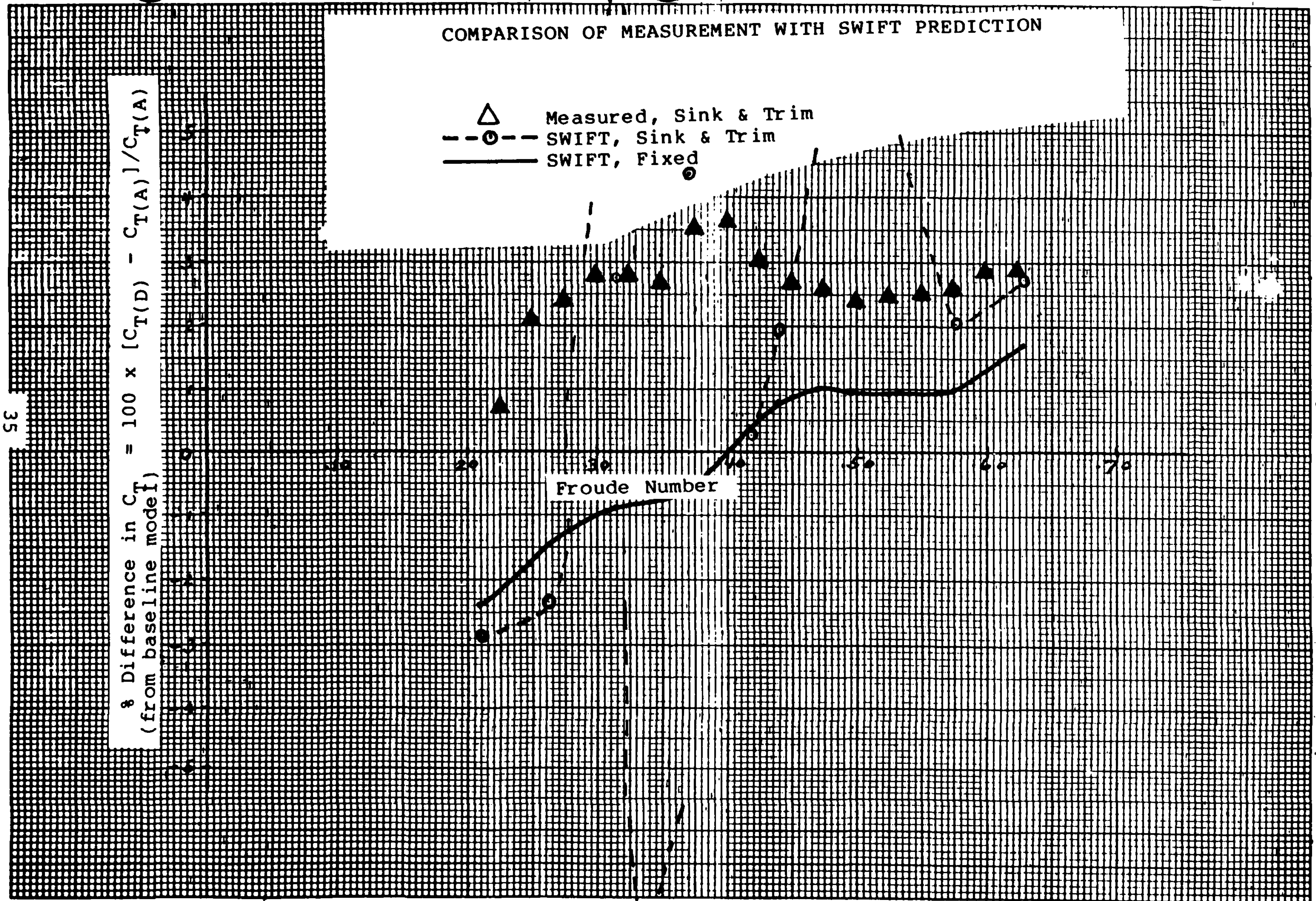


FIG. 27 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL D)

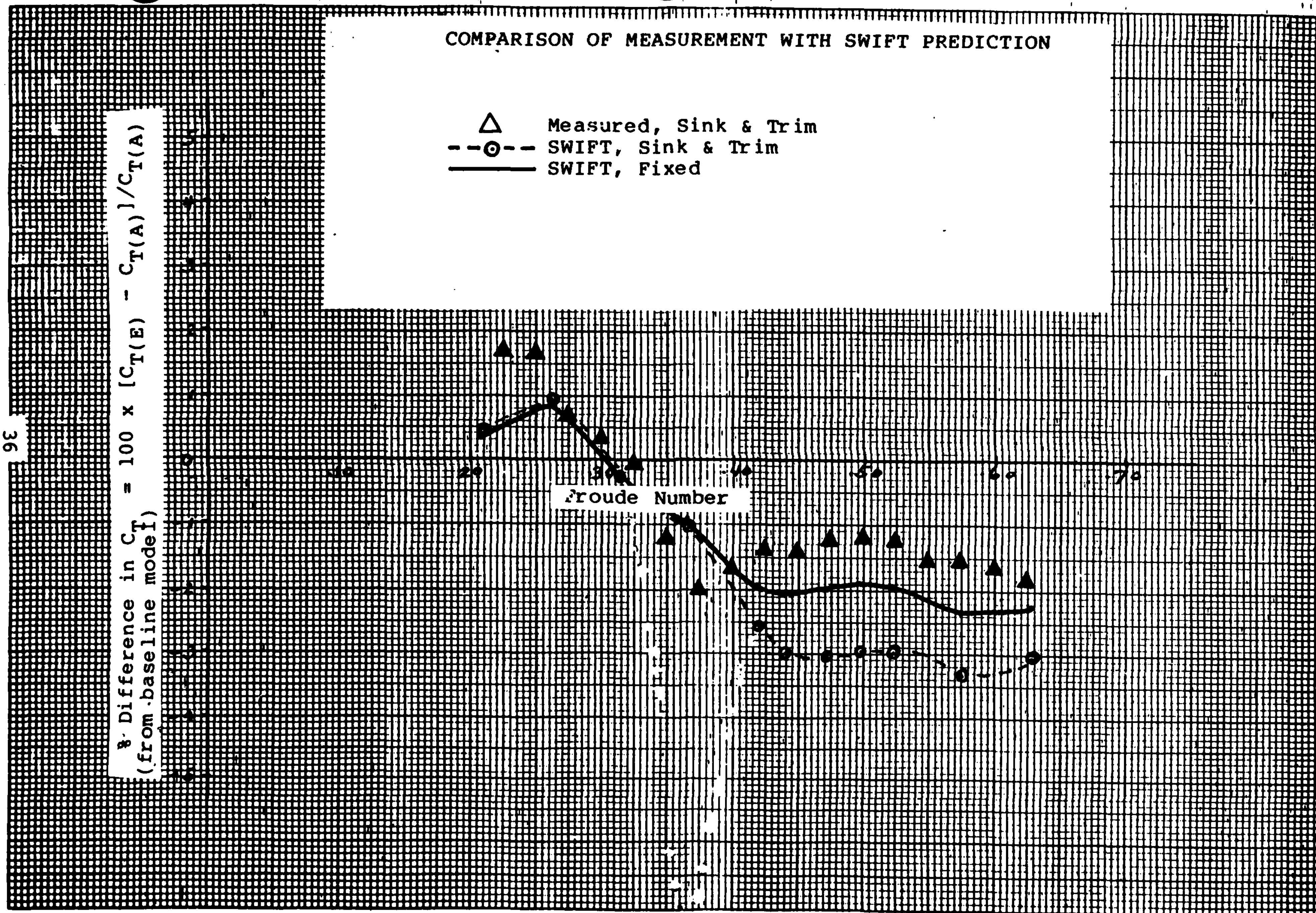


FIG. 28 C_T - DIFFERENCE WITH BASELINE MODEL (FOR MODEL E)